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✓ DTS

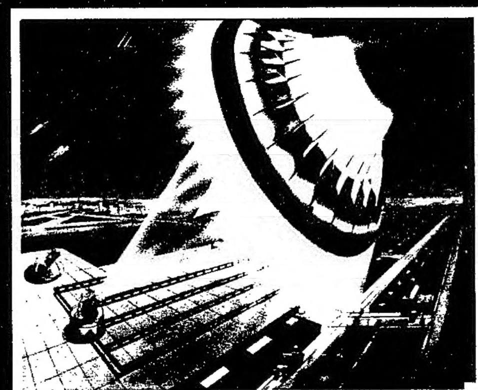
MEMORANDUM FOR PRR (~~Contractor~~/In-House Publication)

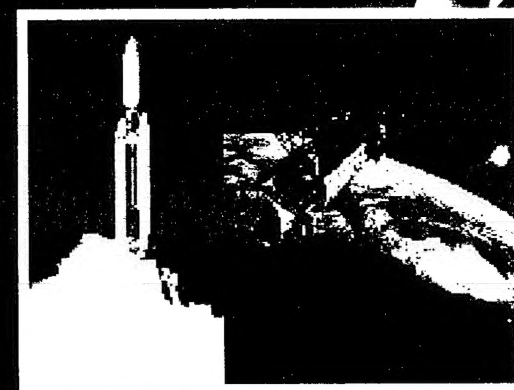
FROM: PROI (TI) (STINFO) 20 May 1999

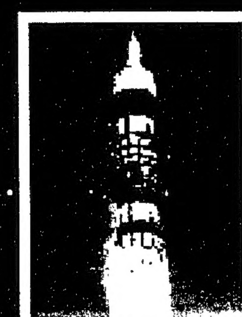
SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-FY99-0104
Jay Levine, "AFRL Propulsion Directorate Propulsion Sciences & Advanced Concepts Division"
[illegible]entation (~~Foreign Release~~) Dist A

Air Force Research Laboratory

Propulsion Directorate

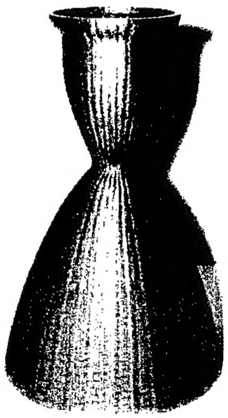




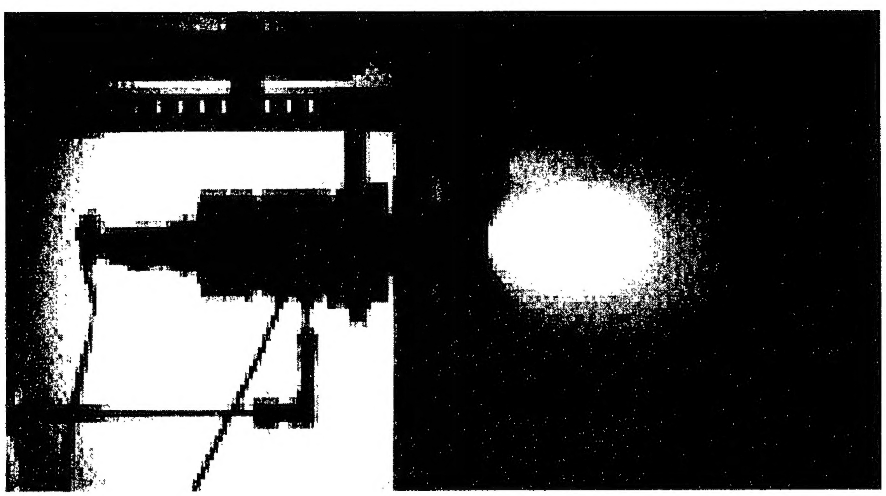


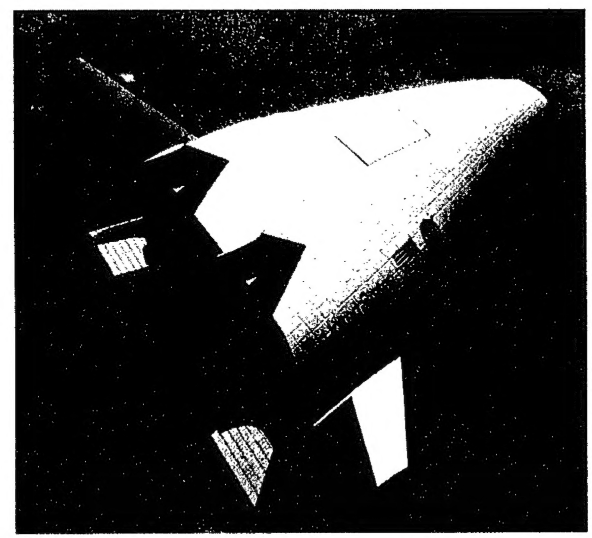
Propulsion Sciences & Advanced Concepts Division

Rocket-Propulsion Research



- Advanced propellants
- Propulsion materials and components
- Aerophysics





Propulsion Sciences & Advanced Concepts Division

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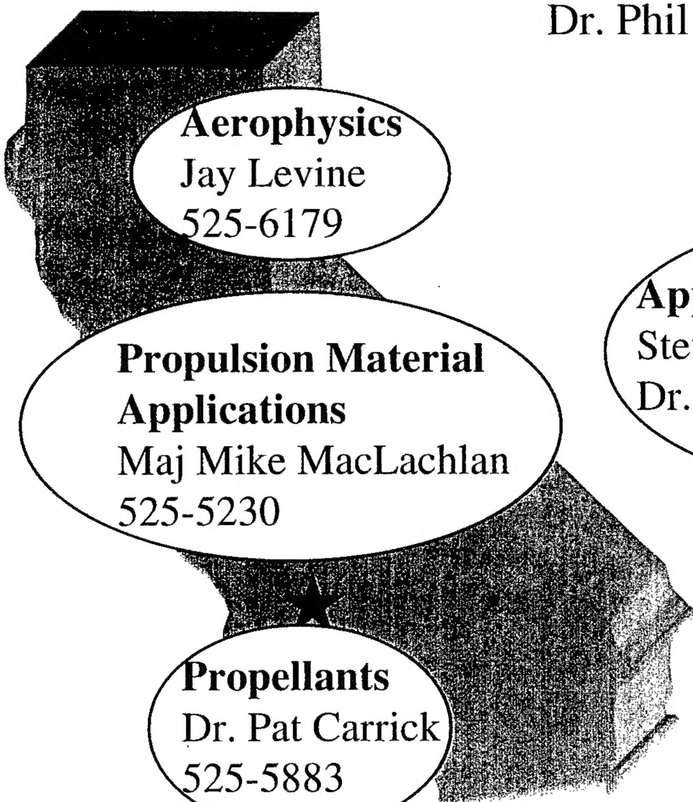
Dr. Phil Kessel 525-5591

Edwards AFB CA



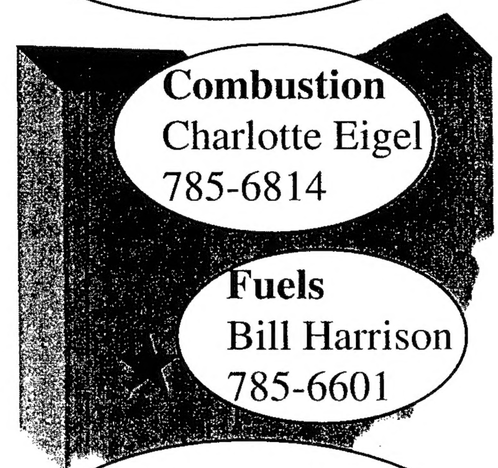
Aerophysics
Jay Levine
525-6179

Propulsion Material Applications
Maj Mike MacLachlan
525-5230

Propellants
Dr. Pat Carrick
525-5883

Applications & Assessment
Steve Mozes 785-9991
Dr. Ray Moszee 525-5534

Wright-Patterson AFB OH



Lubrication
Maj Walt Lauderdale
785-5568

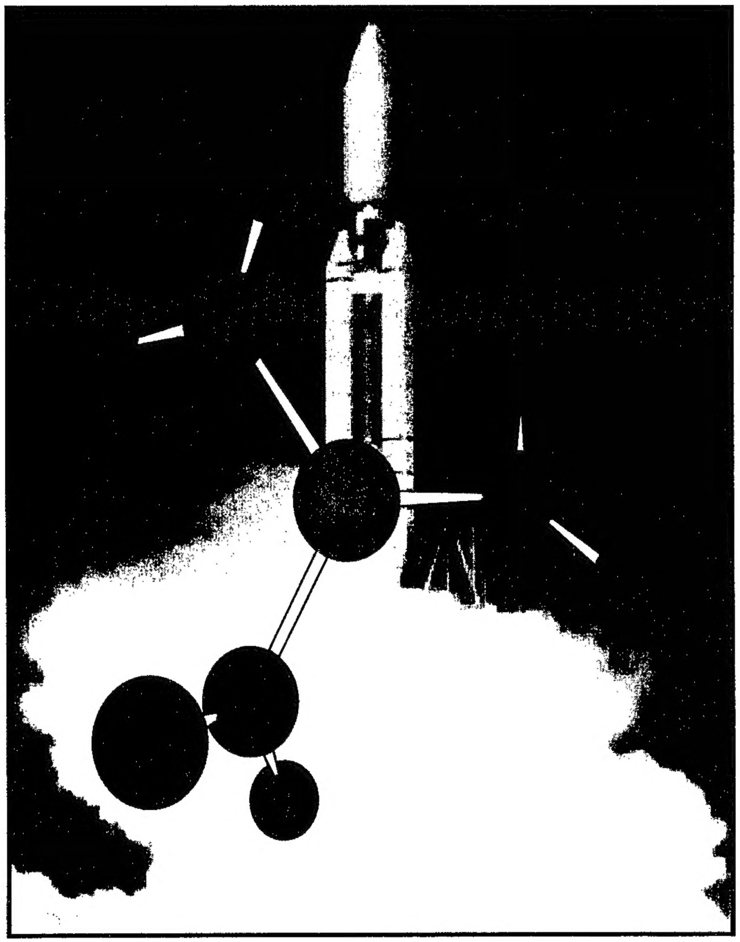
Combustion
Charlotte Eigel
785-6814

Fuels
Bill Harrison
785-6601

High Speed Systems
Maj Kenneth Phillipart
785-5221

AIR FORCE RESEARCH LABORATORY

Technical Specialties

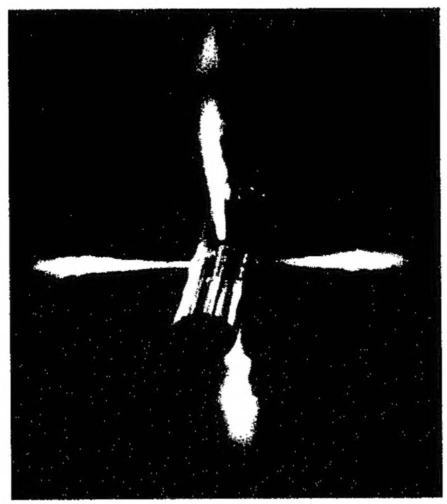


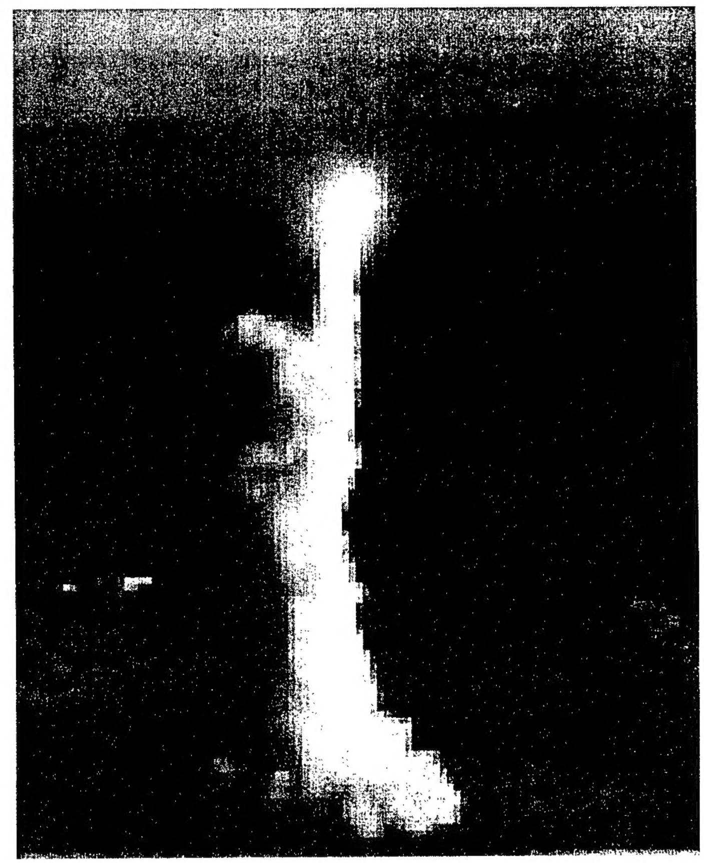
- Combustion
- Hypersonics
- Lubricants and mechanical systems
- Advanced-concept system analysis
- Fuels and propellants
- Plume phenomenology
- Advanced components

Aerophysics

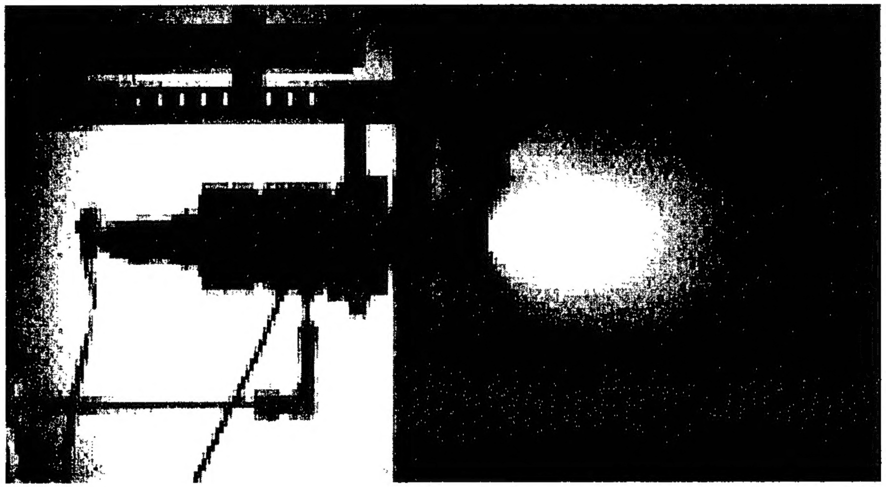
Rocket Combustion–from Propellant Injection to Plume Dissipation

- Non-equilibrium flows
- Supercritical combustion
- Plumes





Nonequilibrium Flow Phenomena



Microthruster concept (1 to 100 μN thrust range)

Payoff

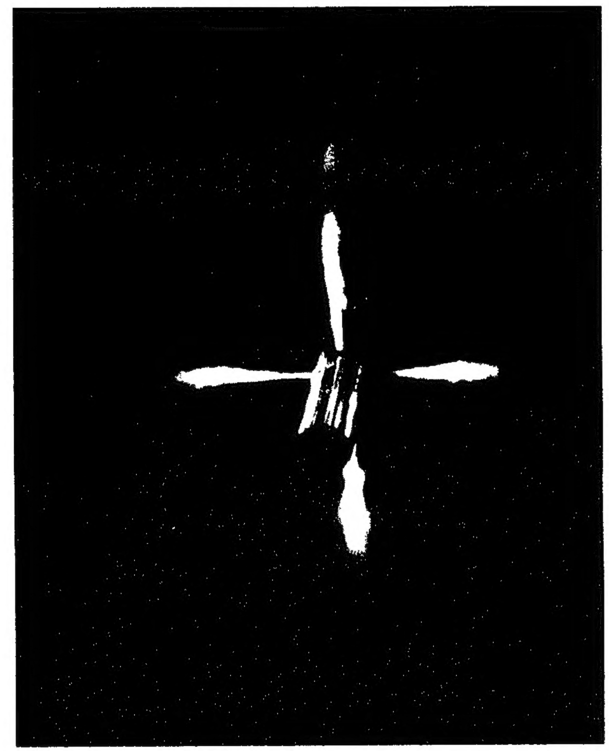
- Reduced production/launch costs for satellites
- Robust tracking via dual mode IR / UV sensors
- Increased spacecraft lifetime & survivability
- Speed deployment of new energetic propellants

Goals

- Identify the key mechanisms which control:
  - The performance characteristics of microthrusters
  - The intensity and spectrum of plume radiation signatures
  - The decomposition and combustion of emerging energetic materials
  - Contamination effects on spacecraft systems
- Design and evaluate novel microthruster concepts
- Provide 3D simulation tools for signature/contamination modeling

Air Force Micropropulsion Mission Requirements

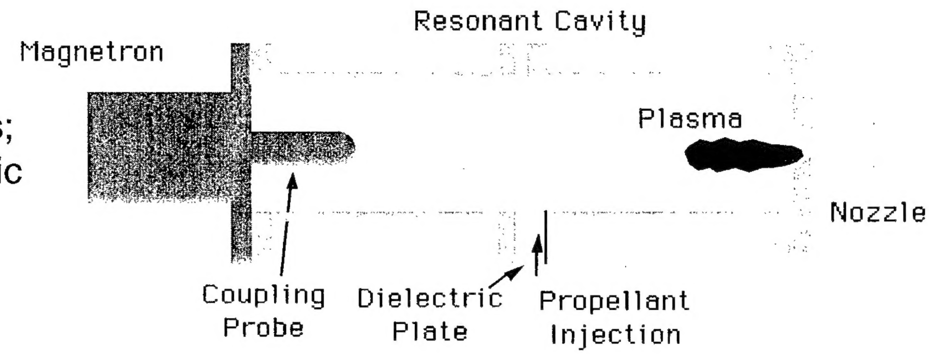
- Near-Earth orbital maneuver requirements
  - Fast response time $\Rightarrow$ High thrust
  - Kinetic kill $\Rightarrow$ Very high thrust
  - Many maneuvers $\Rightarrow$ High specific impulse
- Satellite size requirements
  - Microsatellites (1 g to 1 kg) $\Rightarrow$ Communication/surveillance constellations
  - Small satellites (> 100 kg) $\Rightarrow$ Dedicated satellite communication and surveillance
- A whole range of thrusters is needed to fulfill this broad spectrum of requirements $\Rightarrow$ Chemical, solid, electric, PDE
- Simple scaled-down versions of existing thrusters do not maintain performance levels needed $\Rightarrow$ Critical need for advanced propulsion concepts and approaches



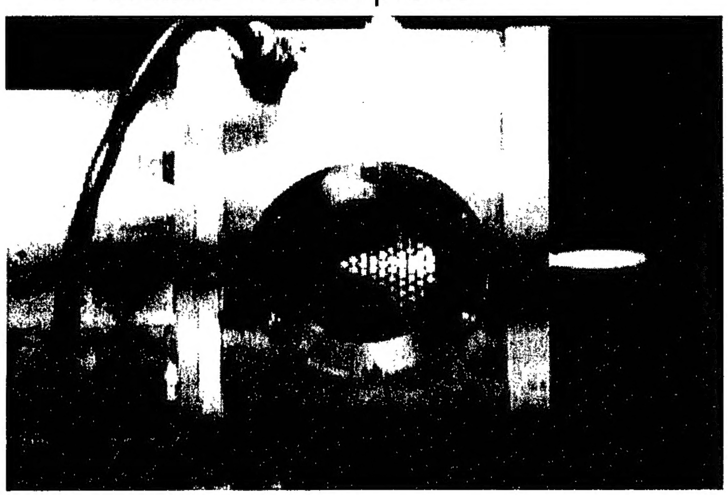
Microwave Microthruster

Description

- Electrodeless, vortex-stabilized arcjet thruster
- Higher specific impulse than chemical systems; more thrust than higher specific-impulse electric devices
- Reduced erosion; increased payload mass; increased lifetime
- Broad range of propellants: N_2, He, H_2, NH_3, H_2O
- Broad range of power levels: 60 watts - 30 kilowatts
  ⇒ Versatile mission profile



Operation: *Magnetron converts electrical energy to microwaves that heat propellant gases to plasma temperatures.*



10-cm-diameter thruster operating at 5 kW

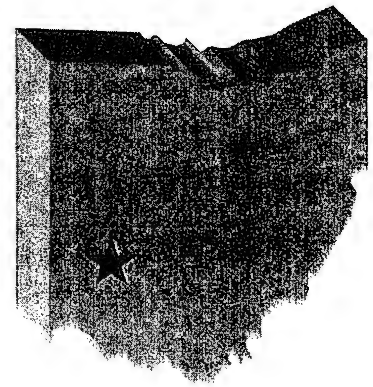
Mission Applications

- Station keeping, attitude control, orbit boost
- Systems : Spartan, Mighty Sat, International Space Station, Shuttle payload boost

Program

- Improve thrust and efficiency by reducing energy loss (heat) to the boundary layer through viscous dissipation
- Joint experimental and analytical effort by AFRL/PRS with Penn State University

Comprehensive Propulsion Research



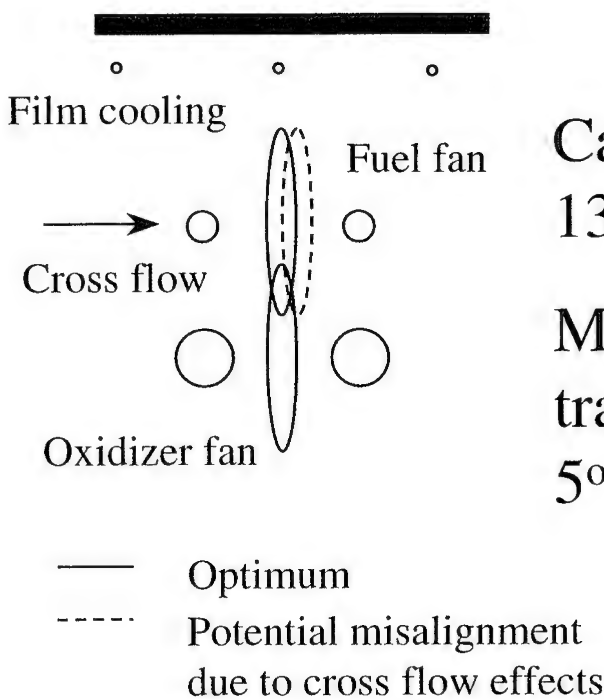
Rocket
Propulsion
- Liquid
- Solid
- Hybrid
- RBCC
- PDRE

Airbreathing
Propulsion
- Ramjet
- Scramjet
- TBCC
- RBCC
- PDE

Combined Rocket and Aeropropulsion expertise

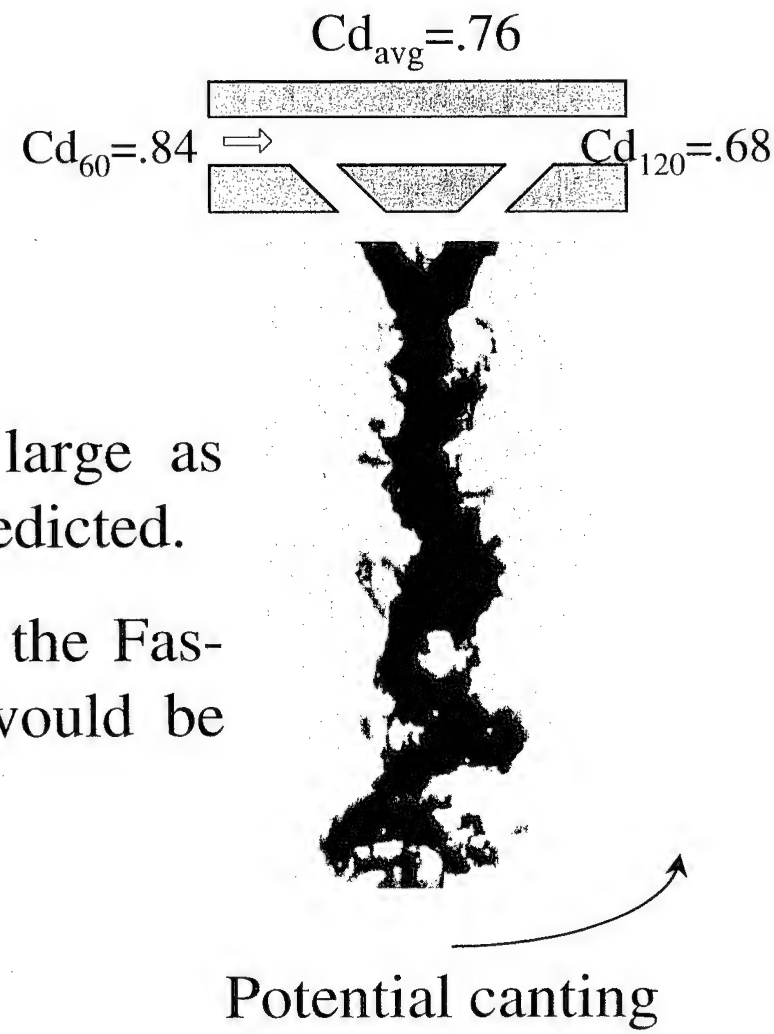
Manifold Cross Flow Can Cause Fan Misalignments and Reduce Chamber Lifetime

A variation in discharge coefficient could shift the spray sngle, potentially allowing oxidizer to reach the wall and cause failure or reduce lifetime.



Cant angles as large as 13° have been predicted.

Misalignment in the Fastrac outer row would be 5° at most.



COLD FLOW INJECTOR CHARACTERIZATION FACILITY

Hardware

Gas simulants	N_2(g), He(g)
Liquid simulant	H_2O(l)
Window Purge gas	N_2(g), He(g)
N_2 mass flow rate	.20 lbm/s
He mass flow rate	.20 lbm/s
H_2O mass flow rate	4.0 lbm/s
Max. test art. press.	2000 psi.
Max. Fuel sim. press.	3000 psi.
Max. Ox sim. press.	3000 psi.
Electrical connections	120V, 208V (1ϕ: 10A, 3ϕ 20A and 50A).

Windowed test chamber with 5.5" of axial injector travel and a linear translating injector stage with 5" total radial travel inside chamber.

Ability to simulate manifold cross velocities to 30 ft/s

Data acquisition and control

16 Channel, 12 Bit National Instruments A/D board run by a 486/33 PC running MS Quick Basic.

Allen-Bradley PLC system for Remote Valve Operation

Mechanical Diagnostics

27 tube traversable linear patternator

Optical Diagnostics

Oxford 20 kHz, 20W Cu vapor laser.
Innova 4W and 10W Argon Ion lasers.
Inj. seed, 2 plse Yag (1.5J at 1064 nm)
Continuum ND6000 Dye laser.
Princ. Inst and Stanford gated CCD cams.
Infinity and Questar LD microscopes.
Aerometrics 2 comp. PDPA.
Malvern 2600 particle sizer.
CCD camera with strobelight and VCR

SUPERCRITICAL DROP/JET INJECTION FACILITY

Hardware

Chamber	Stainless
Optical access	2 facing sapphire windows of 5.25" dia 2 facing slot-shaped quartz (4.75"x0.50")
Max chamb. press.	2000 psi
Chamb. temp.	473 K
Injected fluid	O2, N2, HC, and mixtures
Ambient fluid	N2, He, and mixtures
Injected mass flow rate	400 mg/s
Cryogenic cooler	85 K
Mass flowmeters	up to 10,000 SLPM
Gas detection	O2, CO, HC
Electrical connections	120V, 208V (1ϕ: 20A, 3ϕ 30A and 50A).

Data acquisition and control

64-channel National Instrument AMUX-64T analog multiplexer with special provision for temperature sensor.NB-MIO-16X multifunction I/O board with analog-to-digital converter for Macintosh NuBus computer.

Labmaster DMA Counter/timer/ ADC/ Digital I/O

Scion Corp frame grabber

LabView GUI control interface.

Several PC and Power Macintosh

HP programmable timimg/pulse generator

Optics

Infinity long-distance microscope

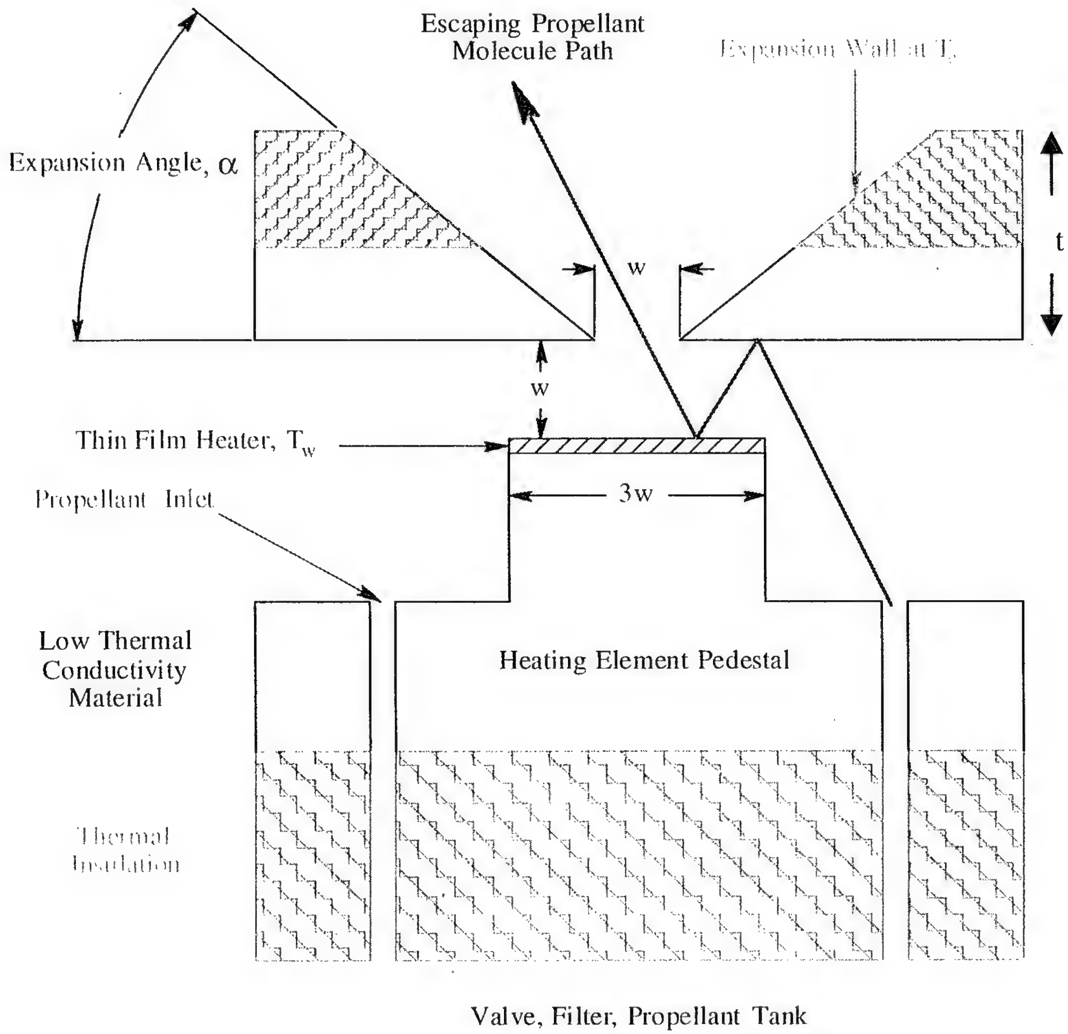
PL-8010 Continuum Nd:YAG pulsed dye laser,

high speed strobe light,

Princeton Instrument camera,

Interlaced PULNix CCD camera

FMMR Design



$w \sim 1$ to $100\ \mu m$
$T_w \sim 600$ to 1200 K
$\alpha = 54.74°$
$t \sim 100 - 250\ \mu m$

Desired:
$w = 100\ \mu m$
$T_w = 600$ K
$\alpha = 54.74°$
$t = 200\ \mu m$
Slot length = 1 cm
No. of slots = 40

PERSONNEL

Aerophysics Branch Organization

(PRSA)

Branch Chief : Jay Levine

Marietta Krissack : Secretary (Shared with other Branches)
Chris Sandstrom : Adminstration and finance (Shared with other Branches)

Working Groups

Plumes
(Tom Smith)

1. Marty Venner
2. Dustin Ziegler

[redacted]

5. *Robert Lyon*
6. *Alan Kawasaki*
7. *Bill Calhoon*

Combustion Devices
(Doug Talley)

1. Victor Burnley
2. Rodger Benedict
3. Ed Coy
4. Pete Strakey
5. Cliff Lusby
6. Mike Mckee
7. Richard Cohn

8. *Tim Auyeung*
9. *Mike Griggs*
10. *Bruce Cheroudi*
11. *Mark Wilson*

Nonequilibrium Flows
(Ingrig Wysong)

1. Andrew Ketsdever

2. *David Campbell*
3. *Dean Wadsworth*
4. *Ghanshyam Vaghjiani*
5. *Angelo Alfano*

Palace Knights

Ron Bates	Stanford	6/99
Mark Archambault	Stanford	5/99

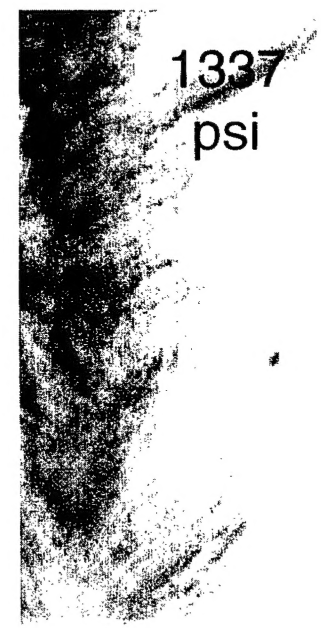
PRESSURE DEPENDENT MIXING LAYER STRUCTURE

Nitrogen/nitrogen system (P_{cr} = 493 psi, T_{cr} = 126 K)

T_{inj} = 128 K, T_{amb} = 300 K, mass flow = 350 mg/s

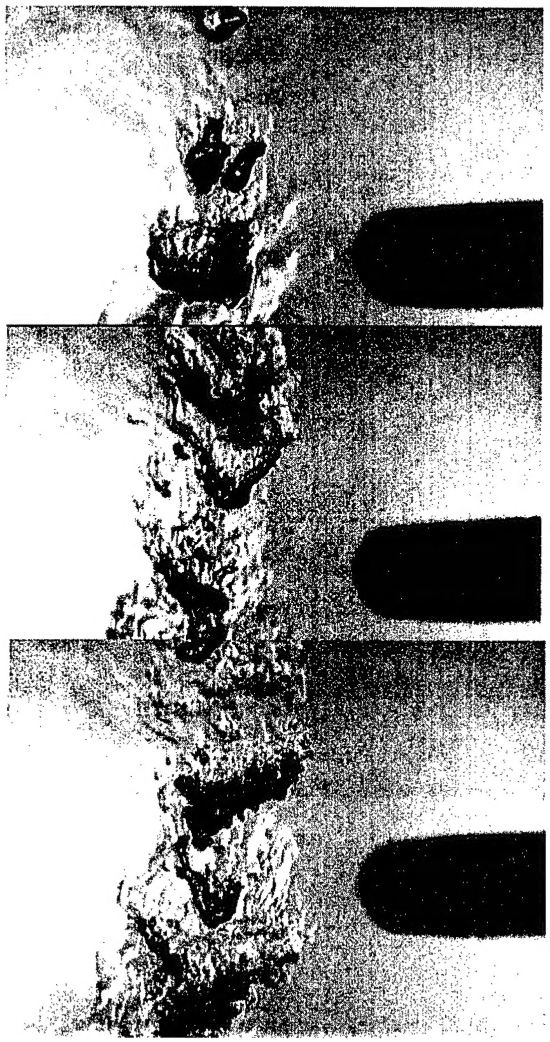
Low Pres.
Subcritical
Droplets

Mod. Pres.
Supercritical
Ligaments



High Pres.
Supercritical
Gas layers

High Pressure and Supercritical Combustion (6.1)



Transcritical Oxygen Drops in Nitrogen

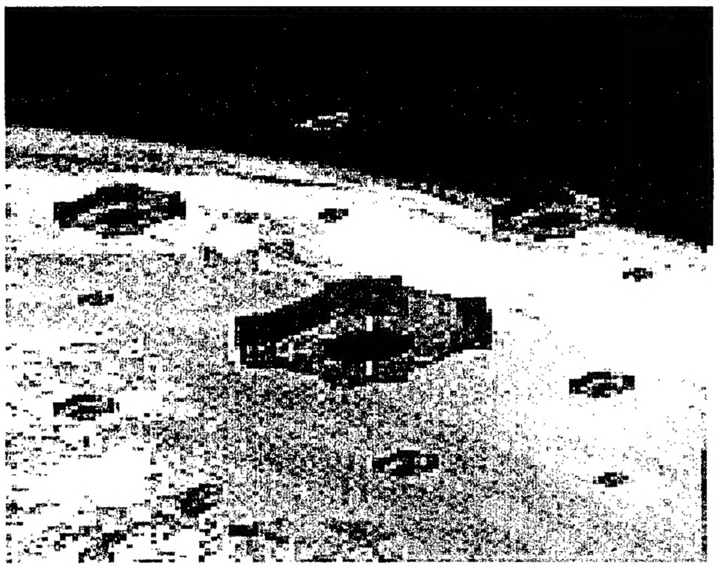
OBJECTIVE

Determine the mechanisms which control the breakup, transport, mixing, and combustion of supercritical droplets, jets, and sprays.

APPROACH

- Piezoelectic cryogenic jet and drop generator in chilled helium.
- Produce acoustic waves using metallic actuators, design resonant modes, focus acoustic waves.
- Reduce optical path lengths.
- Use spontaneous Raman scattering from a frequency doubled Nd-YAG laser.

Basic Research in Nonequilibrium Flow Phenomena



Objectives/Goals

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